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Summary of the ECL2 Workshop

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SUMMARY OF THE ECL2 WORKSHOP

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Abstract

We summarize the ECL2 workshop on electron cloud clearing, which was held at CERN in early March 2007, and highlight a number of novel ideas for electron cloud suppression, such as continuous clearing electrodes based on enamel, slotted structures, and electrete inserts.

INTRODUCTION

The ECL2 workshop was held at CERN, 1-2 March, 2007 [1]. It addressed all methods for suppressing the electron cloud build up, such as reducing the primary or secondary electron yields, modifying the electron dynamics, and changing some beam parameters. The workshop did not discuss beam instabilities or beam stabilization in presence of an electron cloud.

The organizers dedicated the workshop to the memory of Francesco Ruggiero (1957-2007), who had been instrumental in setting up and directing the electron cloud research program at CERN.

The workshop was sponsored by the three European accelerator networks CARE-HHH-APD, CARE-ELAN, and EUROTeV-WP3. It was attended by 35 participants from 16 institutions in Europe, Asia, and America, including 3 representatives from the German enamel industry.

The workshop started with a tour of the CERN NEG coating facility, and was structured in eight sessions spanning over the full two days. A primary topic of the ECL2 workshop was the quasi-continuous electron cloud clearing electrode, based on an insulating enamel layer [2, 3]. Further topics discussed were other types of clearing electrodes, NEG coating, grooved surfaces, slotted surfaces, clearing efficiencies, beam measurements, and impedance issues. Some of these topics were also discussed at ECLOUD'07.

MOTIVATION

The main motivation for the ECL2 workshop was the recent realization, which fully crystallized at CARE-HHH LUMI'06 [4], that the electron cloud may constitute a serious limitation for upgraded LHC injectors, namely for the PS2 and the SPS operated with PS2 beams. The potential problem was revealed in instability and build-up simulations by G. Rumolo and M. Furman, respectively. The actual experience at RHIC [5] and at the present SPS and PS appear to corroborate the predictions. In response to this challenge, an "electron cloud killer" based on enamel coating was proposed by Fritz Caspers in the fall of 2006, and contacts with German industry were established. An earlier "electron cloud killer" proposal, which had been put forward by Peter McIntyre for the LHC proper, involved a microscope cover glass insulating layer attached in-situ on the beam screen [6]. In parallel to the LHC upgrade studies, the electron cloud task force in work package 3 of the EUROTeV linear-collider network is developing solutions against electron cloud build up for ILC and CLIC. A new simulation code, Faktor2, was written for this purpose by Warner Bruns, who, by means of this new code, conceived a different solution for suppressing the electron cloud: a slotted or gridded beam pipe [7].

When comparing the potential of different solutions, a number of aspects need to be considered, such as modeling, prototypes, and beam experiments, suppression efficiency, impedance, vacuum issues, implications and cost. An attempt was made to cover all these points at the ECL2 workshop.

SOLUTIONS

While the installation of continuous clearing electrodes can be challenging in existing machines, they can be an interesting option for new machines with anticipated electron cloud problems, such as the new LHC injectors, or the ILC positron damping ring. Continuous clearing electrodes can be produced by generating an insulating enamel layer on the inside of the beam pipe, above which the electrode is deposited. This electrode can either be made from a low-resistive metal, or it can itself be based on a (now non-insulating but highly resistive) second layer of enamel.

Enamel is a special inorganic glass with a thermal expansion coefficient which can precisely be adapted to its substrate. It may have very high resistance, good adherence to metals, excellent mechanical stability, no electrical charging, very low interaction with organic material, good cleaning properties, and practically no aging. Within bounds, its mechanical and electrical properties can be designed to fit a certain application. Enamel can be applied by dipping, pouring, or spraying. It is dried at 100°C, and then fired at 850°C. For test purposes, several prototype enamel coated beam pipe sections were produced for CERN by a German company.

The optimum configuration of clearing electrodes was investigated, their impedances for two different layouts estimated by two independent programs, GdfidL [8] and HFSS [9], respectively, and the clearing efficiencies explored in simulations. A traveling-wave resonant ring for testing an enamel chamber equipped with an electrode is

clearing electrode	NEG coating
+ install once	- regular activation needed
- never demonstrated (?)	+ demonstrated in several rings
+ for ions clearing and shaking was helpful	+ good for vacuum
+ efficient for ISR coasting beam	- long-term stability?
- impedance	+ impedance

Table 1: Pros and cons of quasi-continuous electrodes and NEG coating.

presently assembled at CERN. This coaxial multipacting test stand with recirculating pulsed power can model beam-induced multipacting without an actual beam in a controlled laboratory environment [10]. The goal is to demonstrate the mitigating effect of the enamel-based clearing electrode with regard to the electron cloud. Some of the relevant enamel properties, such as SEY and PEY, still need to be measured, but so far no fundamental problem has been found.

Experience with other types of clearing electrodes at operating accelerator is mixed. Clearing electrodes were successfully used for ion and dust clearing in the CERN Antiproton Accumulator and EPA [11]. In the DAΦNE electron ring, the ion clearing electrodes were a significant source of impedance and had to be removed from the ring [12]. Some analytical impedance estimates were presented during the workshop [13]. At the CERN SPS, electron-induced sparking of the electrostatic extraction septum has been observed even with a significant bias voltage [14]. The damper pick ups in the SPS were also affected by electron cloud and subjected to different cures including clearing voltages [15].

The slotted chamber structure is intriguing. Electrons passing through the slots, as well as any secondaries they produce, are shielded from the beam field and do no longer contribute to multipacting. In simulations, the slotted chamber is highly efficient in preventing electron build up. A similar structure is actually installed in ISIS, which may explain why ISIS has never observed any electron cloud effect. A disadvantage of this solution is that it requires additional transverse aperture, so that this structure cannot easily be retrofitted in an existing accelerator with given magnet gaps. For a new machine, however, it is an attractive scheme.

Another novel idea, which was suggested by Fritz Caspers during the workshop, is the use of electretes. These are permanently charged materials, e.g. Teflon subjected to electron bombardment during production. Either they provide a permanent electric field which is sustained over several years, or they are self-charged by the beam field. Electretes might allow for an in-situ upgrade of the LHC and the SPS.

More "classical" techniques, previously proposed for suppressing electron build up, include coating with a thin TiZrV NEG layer [16] or with TiN, and grooved surfaces. Some or all of these techniques are being vigorously tested experimentally with beam at SLAC [17], KEK [18], Cornell [19], ESRF [20], and CERN [21]. Results and further plans from all these studies were presented. The simulated beneficial effect of grooves was also discussed [7,22]. An interesting observation was reported from ANKA at FZ Karlsruhe, where the measured heat load in a cold superconducting in-vacuum undulator and the coincident pressure rise indicate the possible presence of an electron cloud at cold temperature and with an electron beam [23]. Some signals for an electron cloud occurring with an electron beam are also seen at CESR [19].

The discussion session focused on a number of open questions:

- Modeling of the electron cloud: the effect of the beam field on secondary and primary emission, the effect of the magnetic field, and the role of ions; numerous issues related to grooves and their correct modeling; the validity of the assumed surface parameters, e.g. difference in rediffused electron component between copper and stainless-steel surfaces.
- Enamel: its secondary and primary emission yields; impedance; stability; detailed study of suppression efficiency; possibility of fitting the enamel coating in the SPS vacuum chamber;
- Other schemes: air-baked copper, radical injection, permanent electric fields (electretes);
- Grooves: in-situ grooving (for SPS);
- NEG vs TiN: long-term stability; self-activation; heat.

Table 1 compares arguments in favor of, or against, clearing electrodes and NEG coating. Table 2 compiles possible attractive solutions for existing and new storage rings, which emerged from the workshop discussions.

new ring	old ring
slotted chamber	NEG coating
enamel electrodes	in-situ grooves
electrete insert	electrete insert
NEG coating	

Table 2: Possible means of electron cloud suppression for a new ring (e.g. PS2) and existing accelerator (e.g. SPS).

Unfortunately, not all the ECL2 presentations could be mentioned in detail for this short summary. Noteworthy are also contributions by T. Demma [24], A. Markovik, G. Poplau [25], O. Malyshev [26], G. Rumolo [27], and further talks by U. Iriso [28, 29].

OUTLOOK

The ECL2 workshop proceedings will be published as joint CARE-HHH, CARE-ELAN, EUROTeV, and CERN-AB report.

REFERENCES

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